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Environmental Problems

For the citizens of seafaring countries, the chief foodstuff is fish and seafood. The search for new fishing areas and the assessment of commercial fish reserves are important socioeconomic objectives. Yet how should people fish so that fish do not disappear? This question is considered in the article below.

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Russia's Fishing Industry and Aquiculture

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In 2009 and 2010, the Russian fish catch was 3.7 and 4.1 million tons, respectively, which is much less than in the Soviet period. The highest catches were in the 1980s, reaching 11.4 million tons, and the first place in this indicator was alternately shared by the Soviet Union and Japan (Fig. 1a).

Annual fish consumption per capita reached 22–24 kg, which corresponded to the medical standards. According to the Russian Federal Agency for Fishery, in 2009, this figure decreased to 13.2 kg. The agency's leadership explains this decrease in fish consumption by the fact that the Russian fleet has ceased to operate outside the Russian economic zone. Indeed, the Soviet fishing fleet harvested 5.2–5.6 million tons of seafood in other regions of the world ocean. In addition, the Soviet Union was able to avoid tough competition for marine resources with other countries by trawling primarily fishes (herring, horse mackerel, mackerel, capelin, ivasi, sardinella, hake, etc.) that ensured the highest catch. Now, since Russia has become a market economy, competition with other countries for oceanic bioresources is inevitable.

The Azov and Caspian basins have long been the main domestic fishing grounds, delivering valuable fish species, such as sturgeon, inconnu, bulltrout, pike perch, and bream. The development of oceanic fishing only after the Great Patriotic War made it possible for marine species, such as herring, cod, and flatfish, to become predominant in Soviet catches. By that time, fish reserves in southern seas had decreased owing to overfishing. While in the past each sea would yield 400 000–600 000 t, at present the yields have decreased by ten times or more (see Fig. 1).

Catches in a relatively small reservoir like the Sea of Azov reached 300 000 t. Until the mid-20th century, only valuable fishes were trawled in excess as subsequent developments showed (Fig. 2). A qualitative change occurred in the 1950s and the 1960s, with the general overfishing superimposed on the consequences of a large-scale harvesting of Azov goby (feed for beluga and starred sturgeon), amounting to 70 000–92 000 t/yr, and other negative factors. This goby trawling resulted in the reduction of food supply for sturgeons, as benthic biocoenoses had been destroyed. At present, the basic bioresources of the Sea of Azov are small pelagic fishes and an introduced species—the Far Eastern mullet, Mugil so-iuy.

Traditionally, the most valuable target species in the Caspian and Azov basins are sturgeons. The most intensive fishing of them in the Azov basin was in the mid-19th century, when about 10 000–14 000 t were harvested every year. In the 20th century, the largest catch was in 1936, 5400 t. In 1995, the official catch of sturgeons was only 790 t; by 2000–2001, it had fallen to 20–70 t; and now it does not exceed 2–4 t. The past 150 years saw a catastrophic drop in the catch of these fishes, by more than 1000 times.

In the Caspian basin, the maximal catches were recorded in 1900–1915 (24 400–30 000 t) and in 1975–1985 (23 800–27 000 t). In 1950–1959, the average annual catch of sturgeons in the Caspian Sea was 13 000 t, which was almost three times smaller than at the beginning of the 20th century. Thus, by the time the cascade of dams was built on the Volga, the natural sturgeon reserves had largely been lost (Fig. 3). The overfishing of all species led to catches that did not exceed 18 600 t in the 1960s and the early 1970s. Increased catches in 1975–1985 (see Fig. 3) totally depended on the activity of fish farms. The disintegration of farms that artificially reproduced resources and poaching in the 1990s put the Caspian, as well as the Azov, sturgeons on the verge of extinction. To restore the Azov and Caspian sturgeon populations, the issue of young fishes should be an order of magnitude larger than now, i.e., 200–300 million issues.

The problem of banning fishing in the Barents Sea has been raised more than once due to overfishing. The crisis of commercial bioresources happened

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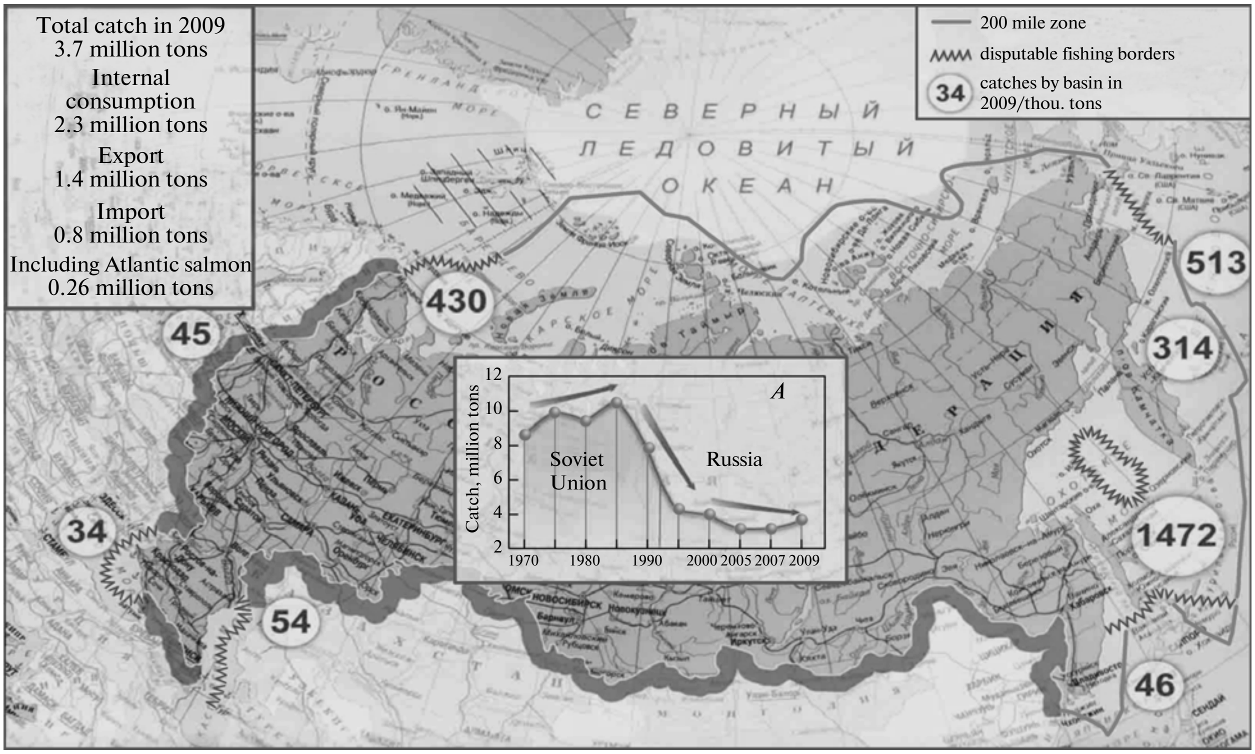


Fig. 1. Main indicators of Russia's fishing industry.

already during the Soviet planned economy. In the prime of oceanic fishing, up to 1.5 million tons of cod and 3–4 million tons of capelin were harvested. The overfishing of the 1950s–1990s led to a resource collapse (Fig. 4).

For the first time over the past 60 years, production indices were calculated for Atlantic cod. The share of withdrawal should not exceed 24% of the biomass of adult individuals. A similar situation occurred with commercial invertebrates of the Barents Sea. In the 1980s, the maximal shrimp catches of 140 000 t were reached. Then its resources degraded. Belated fishing bans led to nothing.

Thus, the general trend for areas of intensive fishing is changing in the catch structure: now the catch is based on small and previously less used species. This is the effect of impact on the upper trophic levels of the marine ecosystems of all European seas and a serious disturbance of natural fish reproduction.

A noticeable restructuring of the species composition of marine biota over the past decades has partially occurred because of the introduction of alien species and other anthropogenic reasons.

At present, large domestic fishing is concentrated in the Okhotsk, Bering, and Barents seas (see Fig. 1). In all fishing zones of the ocean, commercial fishing is the main destroyer of marine ecosystems; this is not a mythical but a real threat, which can completely ruin natural reproduction and destroy trophic chains and the gene pool of commercial biota.

The degradation of natural reproduction of commercial fish is the key problem of the Russian seas. In the Soviet period, overfishing in southern seas was compensated by a large-scale farm reproduction of young pike perch, bream, and sturgeon. At present, the remaining fish farms on the Caspian and Azov seas use archaic technologies, their young fish are unviable, and the return on commercial fish does not exceed 2–4%.

A significant ecosystem imbalance was introduced by alien species, in particular, from the Far East, during the Soviet period. King crab was brought to the Barents Sea from Kamchatka 50 years ago. The peak of its population of 30 million issues coincided with climate warming at the beginning of the 21st century. The crab's fate ended in overfishing (Fig. 5).

The Far Eastern humpback salmon now inhabits a space from the coast of Britain to Pechora Bay. The delivery of alien species to northern basins without projecting ecosystem effects has brought more harm than good. The Far Eastern Mugil so-iuy in the Sea of Azov may also be considered a biological contaminant: it occupied the habitats of sturgeons and other valuable fishes of the Sea of Azov. Kamchatka crab, humpback salmon, and Mugil so-iuy are a positive socioeconomic factor, but, in terms of ecosystem health, these species are an explicit disadvantage.

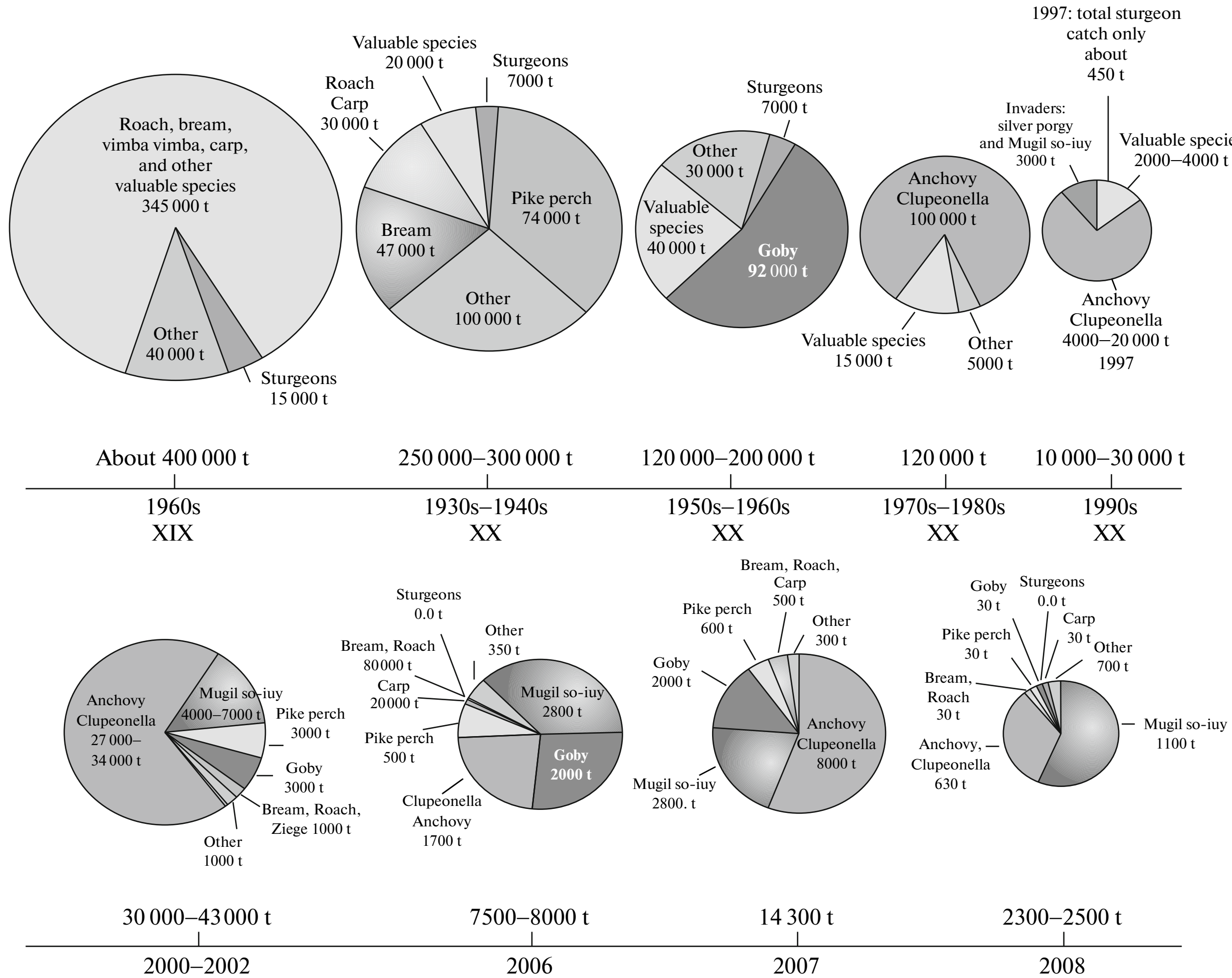


Fig. 2. Quantitative and qualitative comparisons of catches in the Sea of Azov by year.

There are no water areas left in the world where fishing is not regulated by international organizations. In addition, increased environmental requirements on fishing in conventional regions of the open sea should be taken into account. Thus, even if the domestic fishing fleet returns to remote regions of the world ocean, we should hardly expect the catch to reach the former volume. By the optimistic assessment of the Russian Federal Agency for Fishery, in this case, it will be possible to harvest up to 2 million tons a year, which is significantly less than in the 1980s. Therefore, the issue of preserving and renewing aquatic bioresources in domestic waters is becoming especially important. The possible catch in the Far Eastern basin is estimated by specialists at 5–6 million tons, while in 2009 the official catch was 2.7 million tons and, if we add poaching and unaccounted capture, no less than 3 million tons [1]. The latter factor significantly affects the aquatic bioresources of all domestic fishing grounds. Thus, according to the Japanese customs, Russia exports three-to-four times more seafood than is recorded by the Russian "border keepers." The overfishing picture, despite a succession of bans, indicates the weak presence of ecosystem controls over fishing reserves in the fishing practices of not only Russia but also Norway, Japan, and other countries.

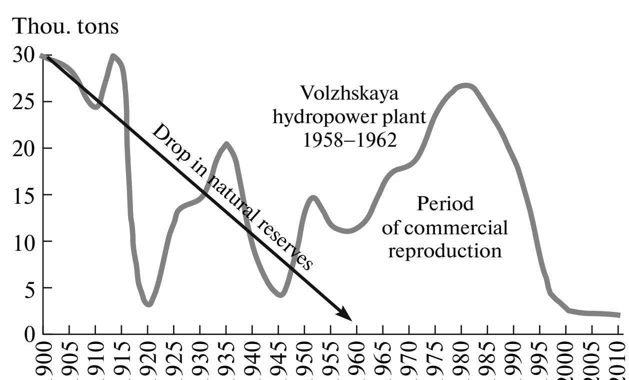


Fig. 3. Caspian sturgeon catch dynamics, thou. tons.

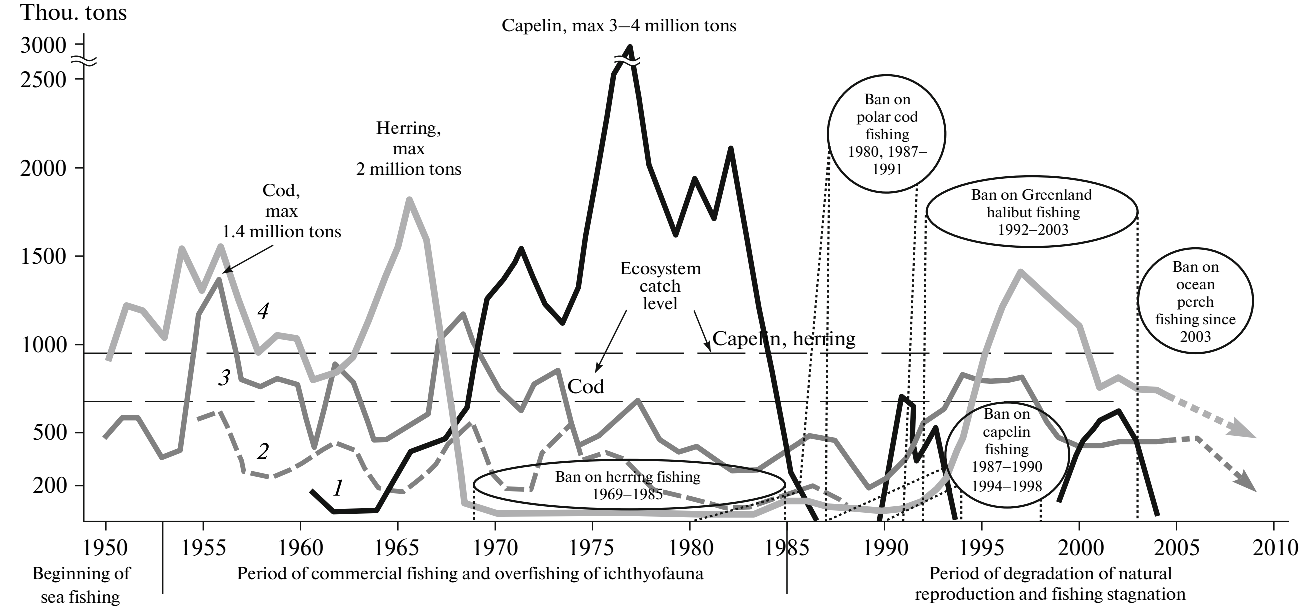


Fig. 4. Stages of degradation of commercial fish reserves in the Barents and Norwegian seas.
(*1*) Capelin, (*2*) cod (Soviet Union), (*3*) cod, and (*4*) herring.

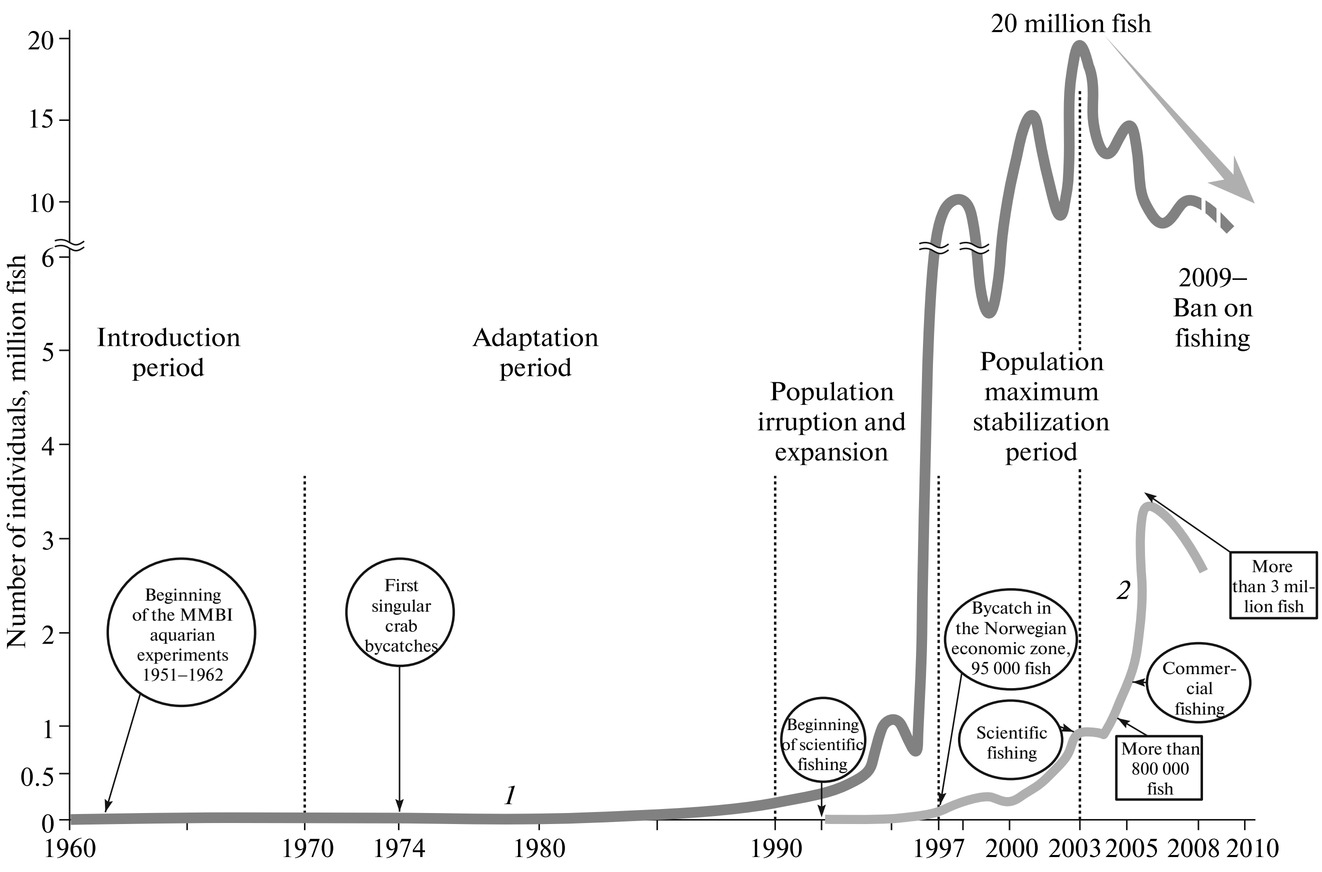


Fig. 5. Consequences of king crab introduction in the Barents Sea basin.
(*1*) Total number of crab and (*2*) total scientific and commercial harvest.

In addition to illegal fishing, another source of unreliable fishing statistics is the imperfection of the current approach to fishing regulation. The basis for the rational use of marine bioresources in the majority of developed countries, including Russia, is to determine the total allowable catch (TAC) for each target species, although in practice this approach often leads to the depletion of reserves rather than to their conservation. Thus, TAC regulation has led to the overfishing of Atlantic cod (see Fig. 4). This context questions the justification of TAC values. Great damage to the studies of the fishing industry's resources has been incurred by the amendment to the Fisheries Act that calls for destroying aquatic bioresources caught for scientific research. This decision was made to counter corruption and poaching. Now annually 15 000–20 000 t of fish and seafood are to be uselessly destroyed at great expenditures. This is harmful for science and contradicts common sense. Would it not be better to give fish to welfare establishments?

One further comment is that acquiring research and educational quotas is associated with numerous bureaucratic barriers, which people have to overcome every year. Meanwhile, fishing organizations of various types of ownership have quotas fixed for ten years and quotas for fishing grounds in the Far East are fixed for 20 years. It would be more rational to allocate research quotas and educational limits for at least five years in advance so that it would be possible to plan long-term ichthyological studies.

The TAC use by species is also incorrect because the overwhelming majority of the existing fisheries are not specialized. The analysis of Russian data on fishing in the Pacific basin shows that truly monospecific are the fisheries of Pacific saury, squid, herring, sardine, mollusks, and sea urchin. All other fisheries are considered to be mixed and, in the majority of cases, multispecific [2]. A similar situation exists in other fishing basins of Russia. As a result, in some fisheries, the bycatch is sometimes several times larger than the catch of target species [3]. Therefore, it is necessary to introduce multispecific fishing forecasts to account for the life cycles, pathways, and food webs of large fish species.

In addition, note that market relations in contemporary fishery make fishermen increase their profits by throwing away undersized, damaged, or simply nonconforming fish [4]. Thus, we are unaware what amount of aquatic bioresources is really extracted due to fishing that is illegal and unaccounted for.

Independent TAC definitions for each "stock unit" may not serve as the basis for rational nature management, and many scientific papers say that it is necessary to regear fishery control principles. "Harvesting" should take into account interrelations between all ecosystem elements exploited. At present, it is necessary to transfer fishing to the methodological basis of the ecosystem approach and to optimize yields from the marine biocenosis and not from the stock unit, as is done today [5]. A strategy of control of bioresource extraction must be worked out depending on the status of the ecosystem of each Russian sea.

In Russia, the scientists of the Murmansk Marine Biological Institute (MMBI), Russian Academy of Sciences, pioneered the development of the ecosystem approach. A complex approach to the Barents Sea studies based on comprehensive knowledge of biota and abiotic conditions was first developed 25 years ago; that is, ecosystem marine research has been conducted for a long time [6]. However, the concept of large marine ecosystems (LMEs) and the term itself have been introduced only in recent years [7]. Large marine ecosystems are regions of the world ocean characterized by their specific bathymetry, hydrography, productivity, and food web. According to international criteria, LMEs cover the littoral zones of river estuaries and the boundaries of continental shelves, as well as the outer limits of the main current systems, and include highly productive ocean regions of at least 200 000 km^2 in area. International organizations legalized a scheme of allocation of the world ocean's coastal waters into 64 LMEs within which more than 90% of bioresources are concentrated. In the United States, China, and European countries, biological and fishing oceanography is largely based on the LME concept. Fisheries, bioproductivity, pollution, socioeconomics, and management should be taken into account mandatorily.

It is clear that the country's fishery restructuring to the ecosystem track is a very complex process. Is it possible under the current regulation monopoly of the Russian Federal Fisheries Agency in all spheres of fishing activities? Obviously, no, because, despite the declared equality before the law, the Fisheries Agency has the right to veto proposals contrary to the opinion of bureaucrats, who explicitly lack a strategic outlook.

Sea fishing primarily needs legislation for an obligatory catch-weighing standard, since vessels that process extracted fish are still weighing the catch by finished product conversion, which creates conditions for understating catches. The complex of other measures in each fishing region may be specific. Thus, for the Barents Sea, the scientists of the Polar Research Institute of Marine Fisheries and Oceanography have suggested three fishing options. For the western part of the Barents Sea, both a new scheme of fishery zoning [8] and proposals to reorganize fisheries have been developed, which may be considered steps toward the implementation of the ecosystem approach—the so-called blocked quotas for multispecific fishing, when a fishing license includes all commercial species that are present in a given fishing gear or possible harvesting is regulated by limiting the fishing season [3].

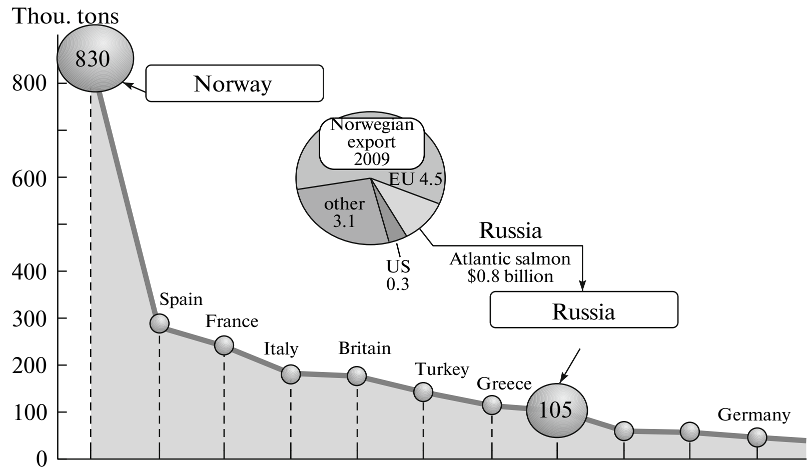
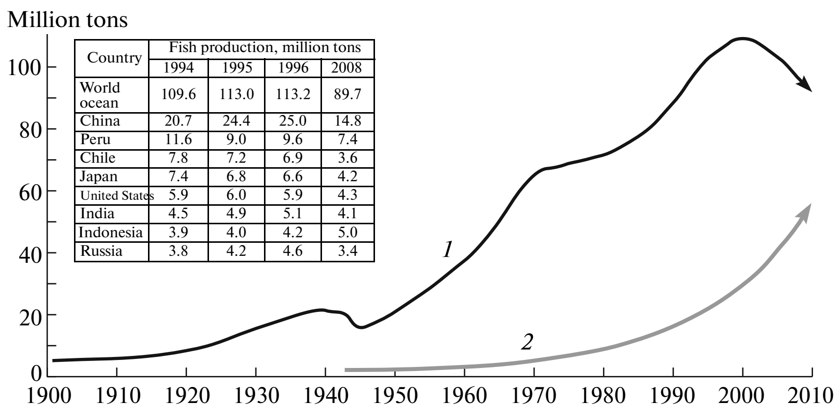


Fig. 6. Global fisheries and aquaculture production in the 20th century.



Country	Fish production, million tons			
	1994	1995	1996	2008
World ocean	109.6	113.0	113.2	89.7
China	20.7	24.4	25.0	14.8
Peru	11.6	9.0	9.6	7.4
Chile	7.8	7.2	6.9	3.6
Japan	7.4	6.8	6.6	4.2
United States	5.9	6.0	5.9	4.3
India	4.5	4.9	5.1	4.1
Indonesia	3.9	4.0	4.2	5.0
Russia	3.8	4.2	4.6	3.4

Fig. 7. Aquaculture products in European countries.

The most realistic and civilized way of increasing production of aquatic origin is to develop aquaculture in all its forms. Seafaring countries have been developing fish-farming as an independent industry since the 1960s (Fig. 6). Therefore, an urgent objective of Russia is the search for efficient fish-raising technologies, adapted to the domestic mentality. Today global fishing has reached its ceiling, about 100 million tons a year. As the natural reproduction of bioresources declines, the only acceptable and reasonable way out is to develop aquiculture. Over a quarter of a century, commodity output in China, Japan, Norway, Peru, France, Turkey, and Southeast Asian countries has reached 60 million tons. China alone annually produces 32 million tons.

Norway, located in the polar region and traditionally regarded as a leading fishing power in the world, has reached an impressive success (Fig. 7). It annually raises up to 800 000 tons of salmon alone. Our neighbor in the Barents Sea has explicitly shown what can be achieved by rational oil and gas development and reasonable capital investment in specific commercial salmon breeding. The total value of aquiculture exports from Norway in 2009 was $7.7 billion.

Russia's share in global aquiculture production is very small. Fish raising in the basin of the Black and Azov seas reached about 30 000 tons a year in the first decade of the 21st century. About 100 000–115 000 tons a year are raised in all Russian basins. As a result, Russia annually imports $800 million worth of fish from Norway alone. According to forecasts, if the current inert scenario prevails, commercial fish production will not exceed 200 000 tons a year by 2020, which is a mere nothing compared to the performance of other countries. The target species raised in Russia are mainly carps, while much more valuable sturgeons, whitefishes, and salmonids comprise a tiny portion.

As aquiculture grows, its influence on the health of littoral marine ecosystems is becoming more visible. Two factors are most vivid: the organic pollution of bays and fiords and the "contamination" of wild (nat-

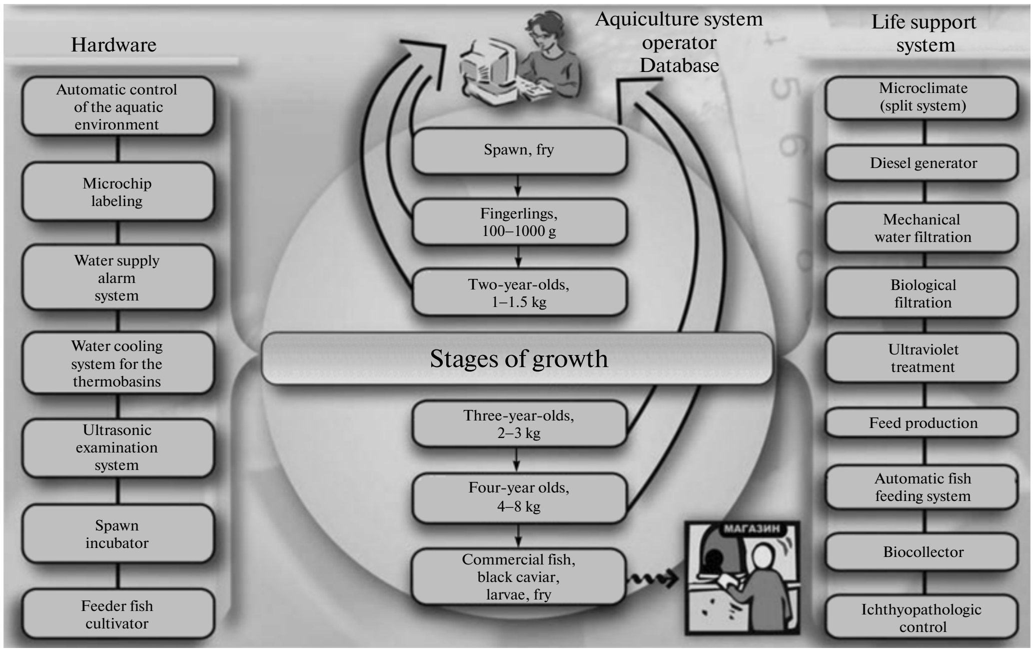


Fig. 8. Structure of sturgeon growing in closed water-supply facilities.

ural) fish populations with fugitives from aquafarms. A case in point is salmon raised offshore western Norway. Marine farms keep up to 350 000 species. During emergencies and storms, some of the fish escape into the sea and take to the spawning grounds of wild salmon in the rivers of the Kola Peninsula. The first captures of alien fish from Norwegian farms were recorded in 2001. The annual flow of invasive species has reached thousands. Modified fish ousts wild salmon in the Murman breeding grounds [9].

In Russia, academic and fishery research institutes have developments aimed at marine and freshwater fish aquaculture. The Murmansk Marine Biological Institute has experimental and pilot developments for raising cod, flatfish, and other Barents Sea fishes [10]. The survivability of various fishes raised in high latitudes is 26–66%. These are good indicators because marine fishes with pelagic spawn are characterized exclusively by high mortality at the early stages of development. According to expert estimates, it is possible to raise 8000 t of salmonids, 3000 t of mussels, and 4000 t of seaweeds.

In the Barents Sea, the total aquatic area where marine farms can be organized is about 6000 ha [11]. Western Murman is promising for organizing full-system farms for the commercial raising of Atlantic salmon, cod, halibut, haddock, arctic char, and plaice. Here it is possible to grow commercially cold-water trout and cod and to cultivate mussels, seaweed, and king crab. The most effective and economic is the commercial raising of Atlantic salmon and cod in cages [12].

The findings of basic research into the biology of sturgeons, carried out by the RAS Southern Research Center jointly with the Astrakhan' State Technical University, have allowed specialists to improve the technology of closed water systems for raising fish at each production stage [13] (Fig. 8). New intensive technologies help raise the commercial products of a mean mass of 1.5 kg in a year and 3 kg in 2–3 years, as well as sturgeon producers that mature in 3–4 years and spawn every year. Our method of growing is more efficient than all the known approaches.

The developed technology is competitive and economically feasible. In a short time it has produced results that surpass Western standards by 2–4 times in useful output and reduce mortality at all stages of the production cycle. In addition to high-quality marketable products (sturgeon meat and food caviar), regulated modular systems for commercial fish farms can produce seeding material (larvae and fry). The introduction of our technology may create a foothold for the system of fish farms and associated operations on the Azov and Caspian seas. Twenty farms currently use it.

It is necessary to adopt proactive measures to develop aquaculture (a law on aquaculture), a target sturgeon development program, a Russian network of cryobanks to preserve biodiversity and replenish the list of cultivated hydrobionts, and conditions for the development of small and medium businesses in the fishing industry. In order to remake Russia a caviar producer, it is necessary to implement a federal investment project of $1 billion over 10–15 years. On the

whole, Russia more than ever needs a distinct, long-term scientific and socioeconomic policy in fish rearing for sale.

Today the government should work out a policy according to which we eat what our ancestors have eaten and restore our local faunas; otherwise, we will have to import products. It is time to define our position clearly.

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